

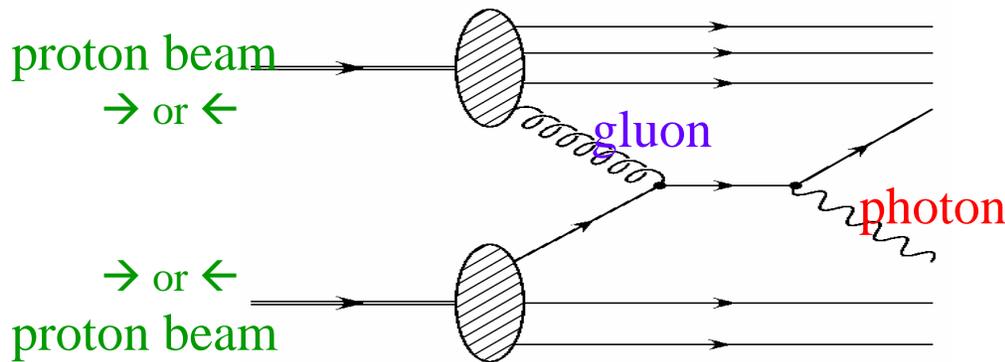
Study of Proton Helicity Structure in Polarized $p+p$ Collisions at PHENIX

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for the PHENIX collaboration
DIS2007 Munich

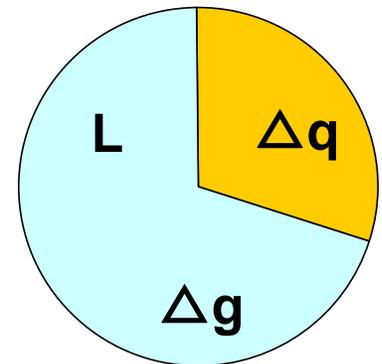
RHIC PHENIX

- The first polarized proton collider (up to $\sqrt{s}=500\text{GeV}$).
 Gluon in proton interacts in leading order process.

Example: direct photon production



Proton spin component



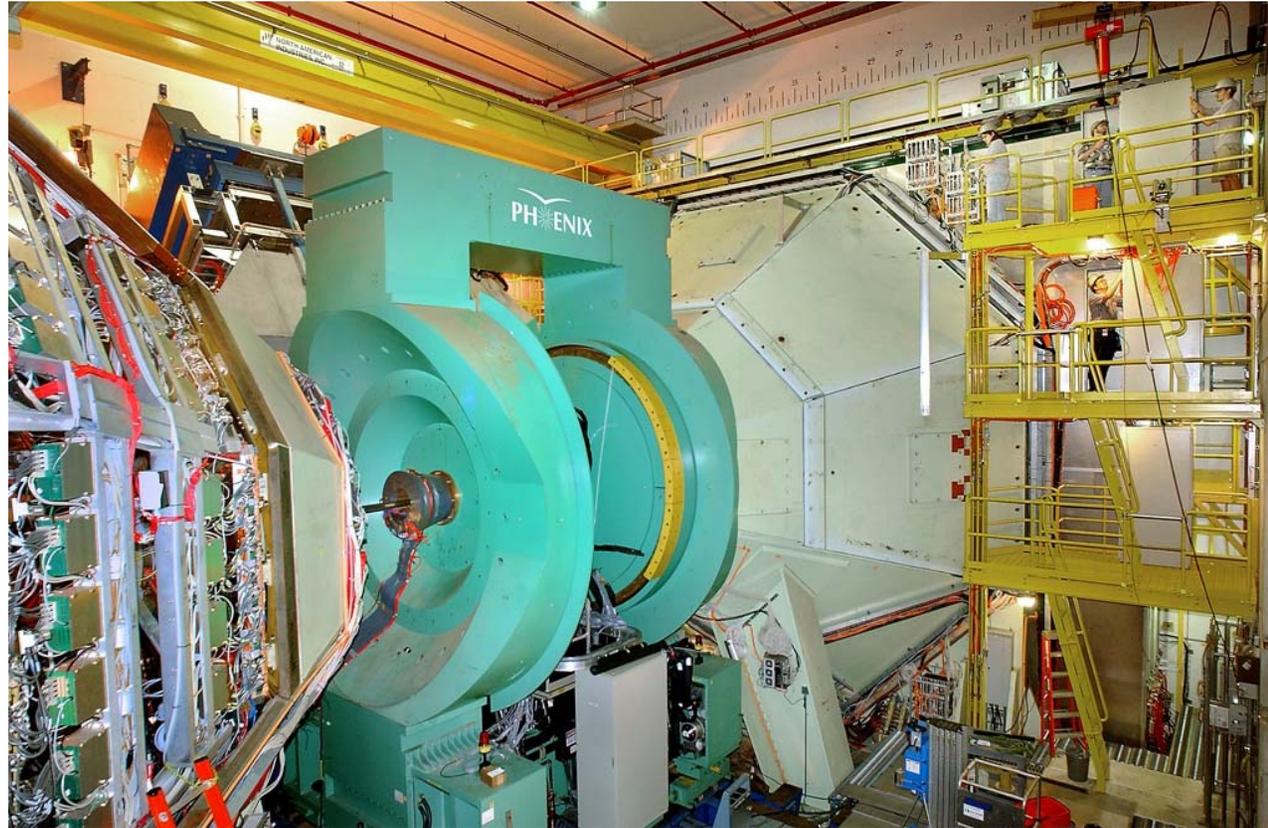
- The missing proton spin component (Δg) can be probed by the production asymmetries.

$$A_{LL} \equiv \frac{1}{P^2} \cdot \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$$

PHENIX detector

Central arm ($|\eta| < 0.35$, $2 \times 0.5\pi$)

Muon arm ($1.2 < |\eta| < 2.4$, 2π)



PHENIX detector

Central arm ($|\eta| < 0.35$, $2 \cdot 0.5\pi$)
 Muon arm ($1.2 < |\eta| < 2.4$, 2π)

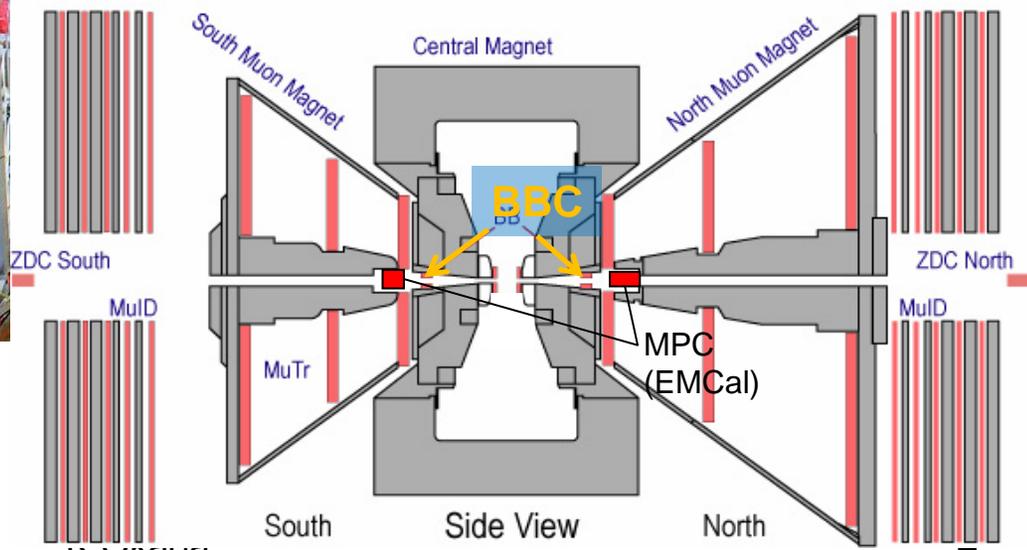
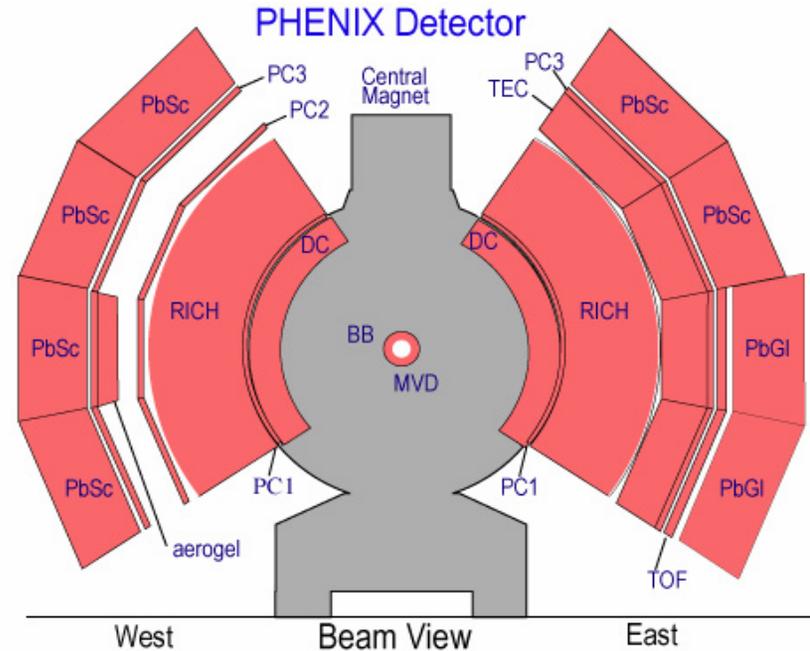
Collision counter
 BBC, ZDC

Trigger
 EMCal and/or RICH
 MPC (forward EMCal)
 Muon ($E > \sim 2\text{GeV}$)

Longitudinal spin collision
 ($\sqrt{s} = 200\text{GeV}$)

$\int L(\text{/pb})$

| | |
|------|-----------------------|
| 0.35 | (2003:Run3) |
| 0.12 | (2004:Run4) |
| 3.4 | (2005:Run5) |
| 7.5 | (2006:Run6) pol~60%!! |
| 70 | (2008:Run8) (plan) |



Cross section measurement

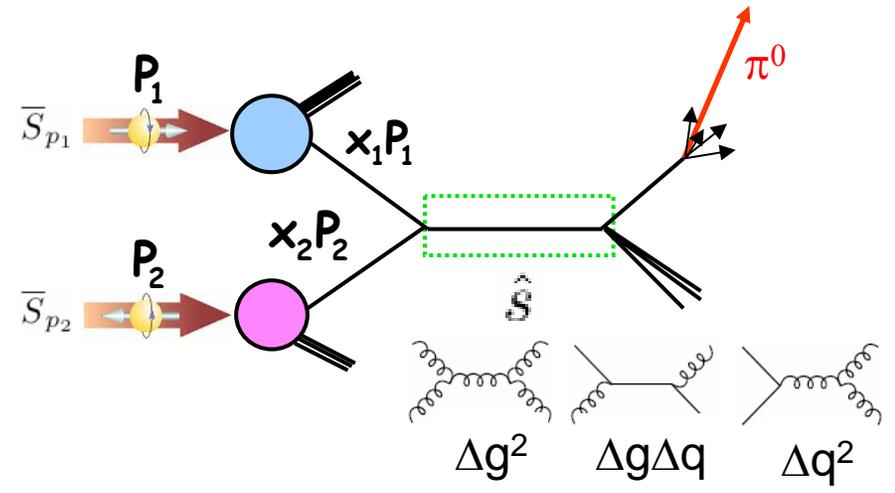
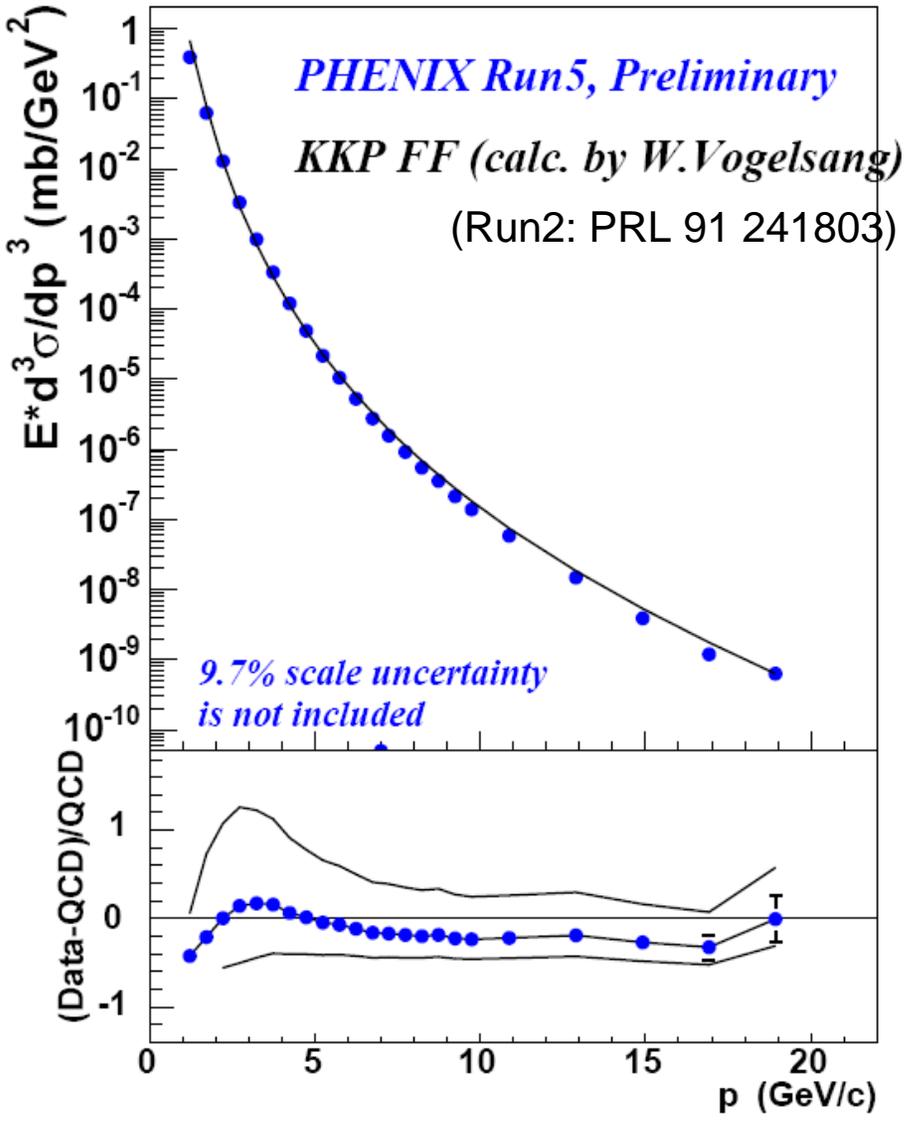
- Before going to asymmetry measurements, we need to confirm the applicability of factorized pQCD.
 - pQCD calculation is used to extract Δg (for example sensitive x region)
 - Is the PDF measured by DIS experiments valid for $p+p$ collisions?

— Luminosity measurement by our beam-beam counter (BBC)

$$\int L = \#BBC / \sigma_{BBC}$$

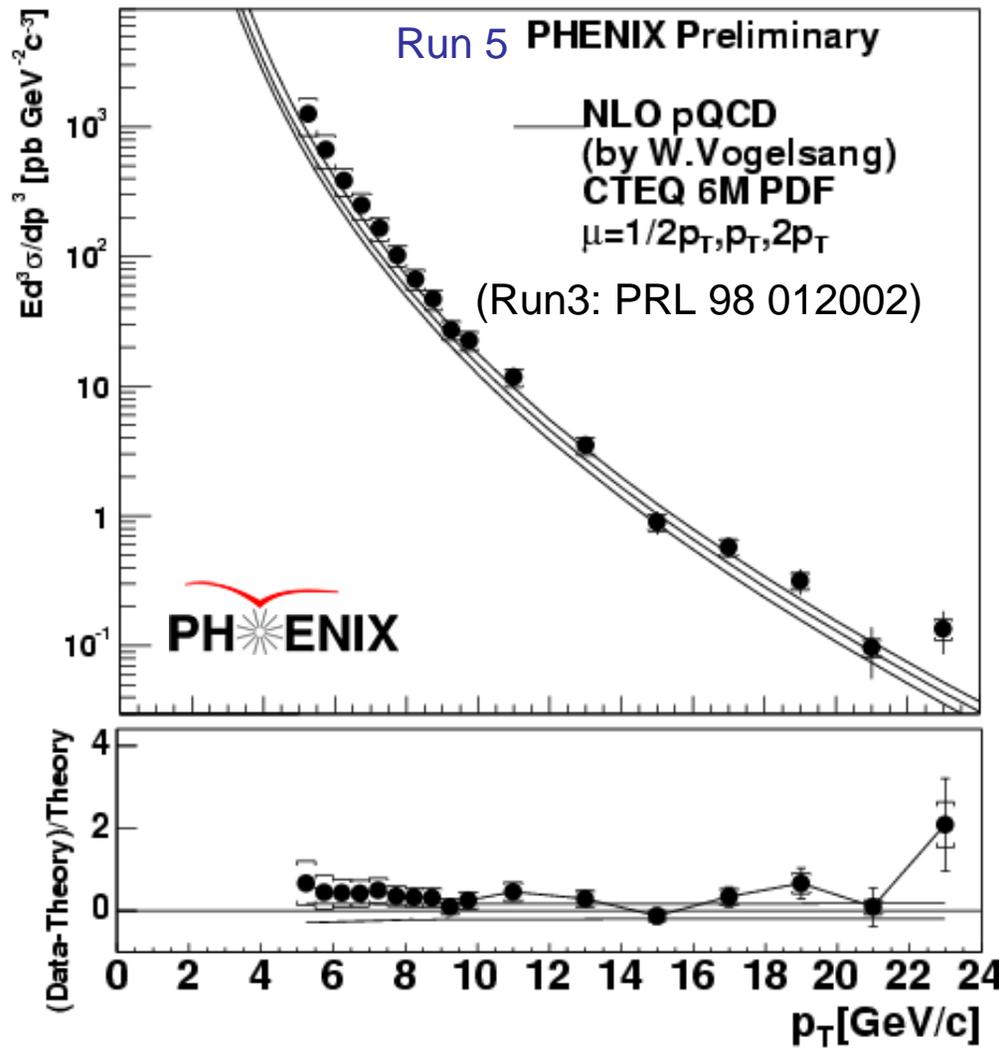
σ_{BBC} is determined by the transverse beam size measurement
 $\#BBC \text{ rate} = \sigma_{BBC} \cdot L$
 \uparrow (beam current)² / (beam size)²

Cross section measurements

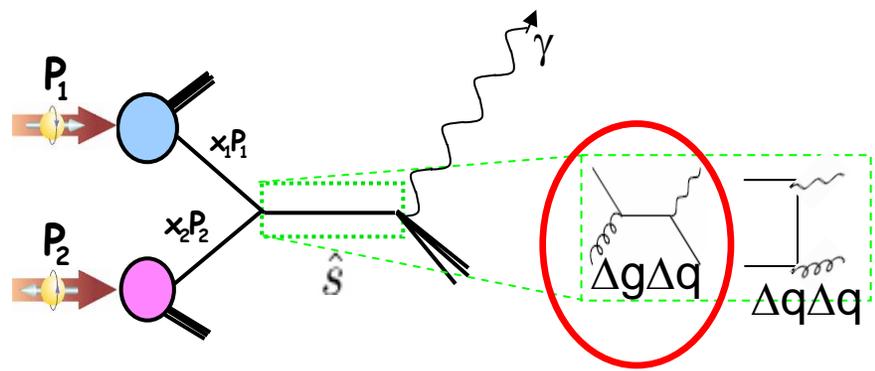


pQCD calculation works well.

Cross section measurements



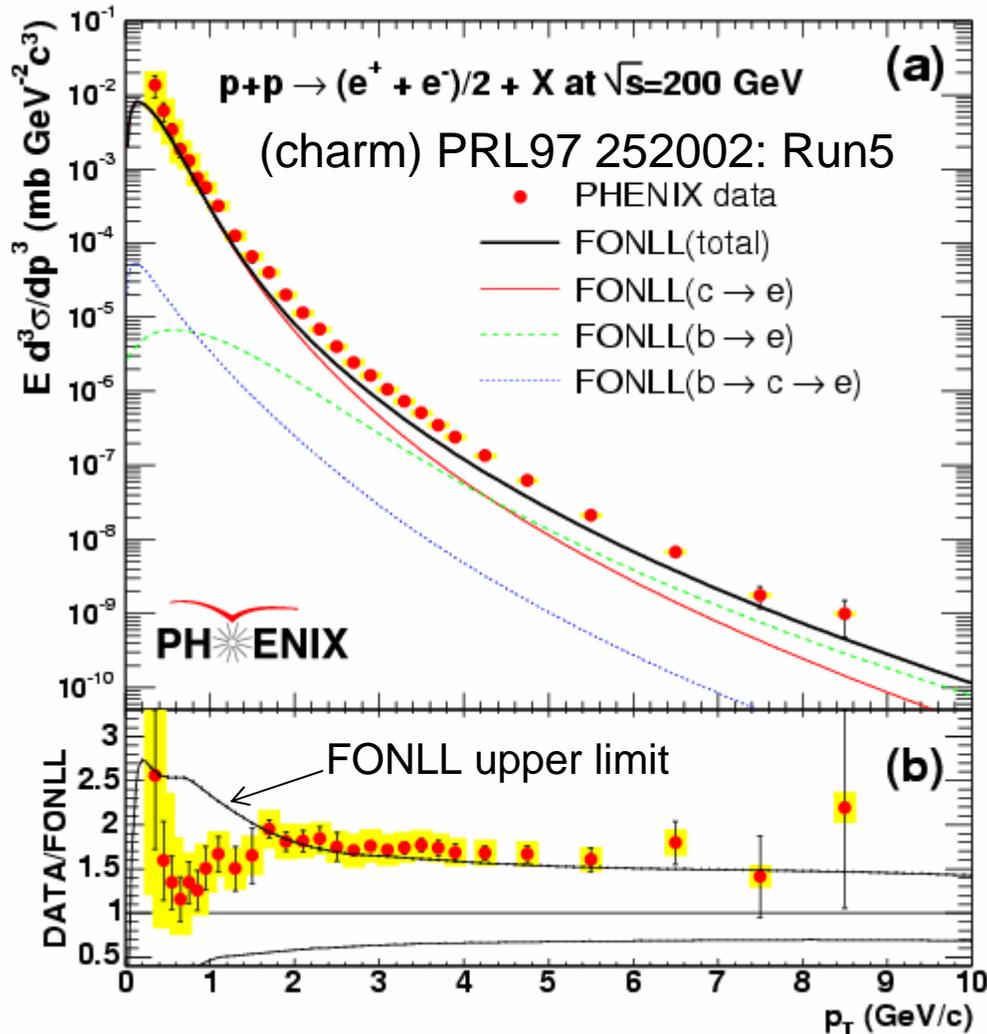
Direct γ



pQCD calculation works well.

Cross section measurements

Un-pol



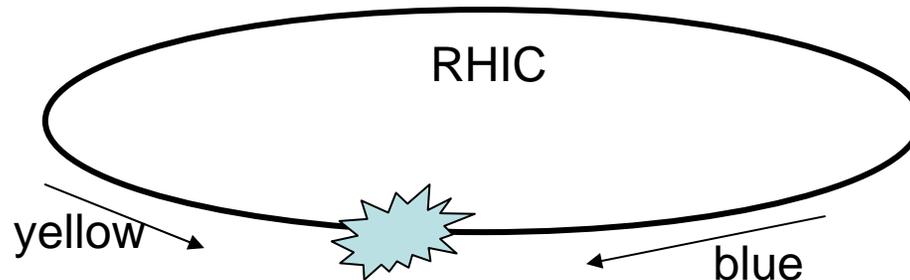
Electron
 (from Charm, Beauty)

$$gg \rightarrow Q\bar{Q}$$

$\Delta g \cdot \Delta g$

pQCD calculation works well.

Asymmetry measurement



120 bunches (revolution time = 1.2 [μ s])

Yellow + - + - + -
Blue ++ -- ++

$$A_{LL} = \frac{1}{P^2} \cdot \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}$$

$$R \equiv \frac{L_{++}}{L_{+-}}$$

Relative luminosity
determined by BBC,ZDC counts

Check relative luminosity measurement

Using the same hard scattering as the luminosity measurement

⇒ Need to check if there is no A_{LL} in BBC

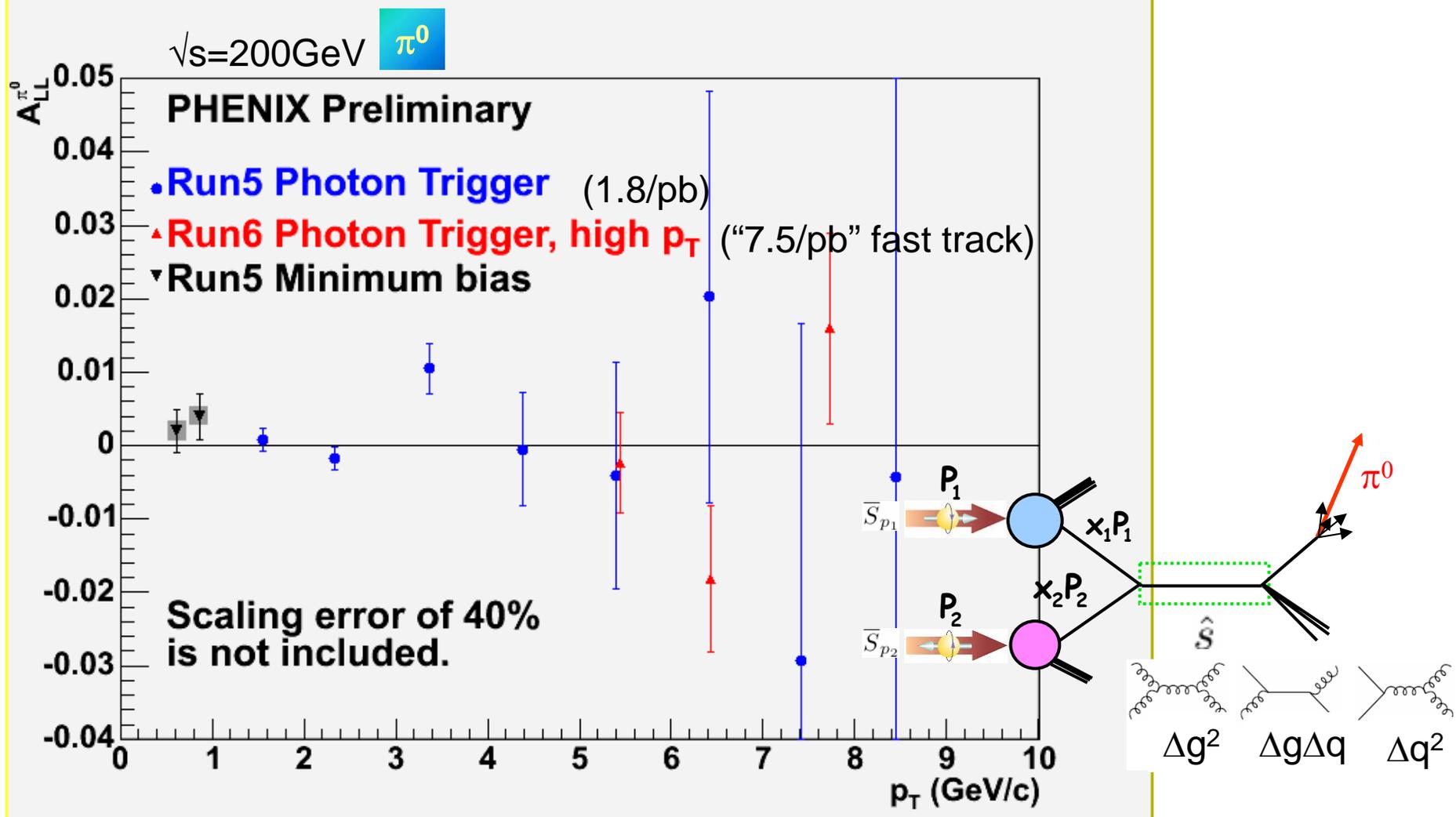
⇒ Comparison between BBC and ZDC

Check bunch related systematic uncertainty

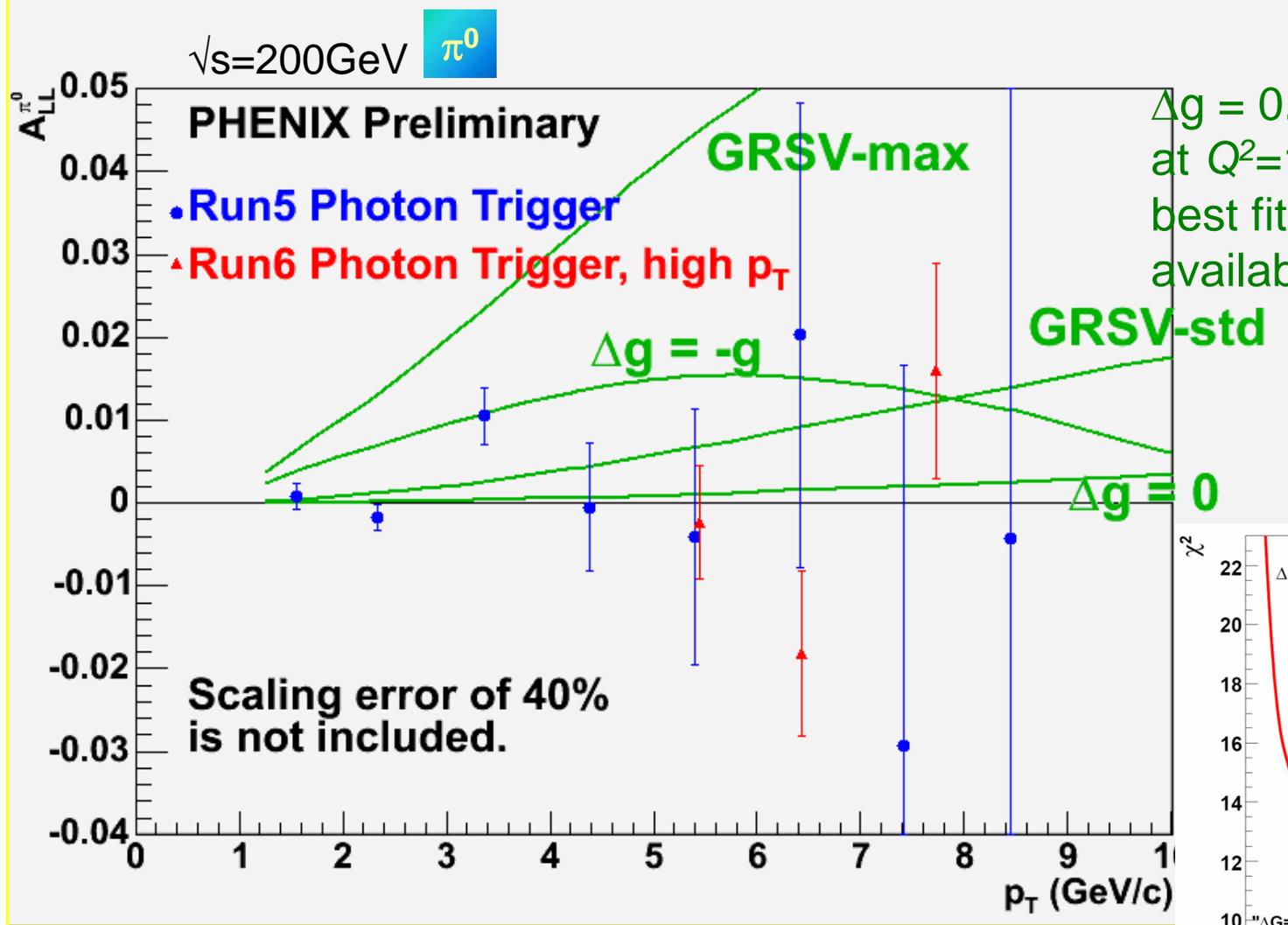
Enough statistics in a bunch ⇒ check rate per bunch

If it's not enough ⇒ assign random spin pattern ⇒ confirm null asymmetry

Mid rapidity π^0 asymmetry

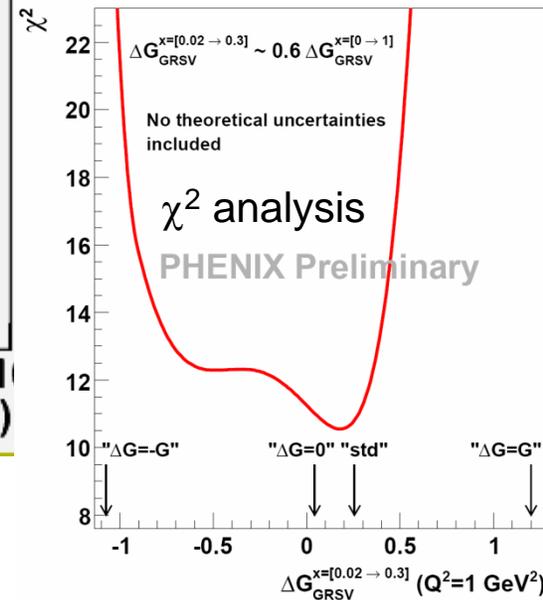


π^0 asymmetry with theory calculations



$\Delta g = 0.42$
 at $Q^2=1(\text{GeV}/c)^2$
 best fit to DIS data
 available in 2001

It is consistent to $\Delta g=0$ and even negative Δg .



A way to access higher x_{gluon}

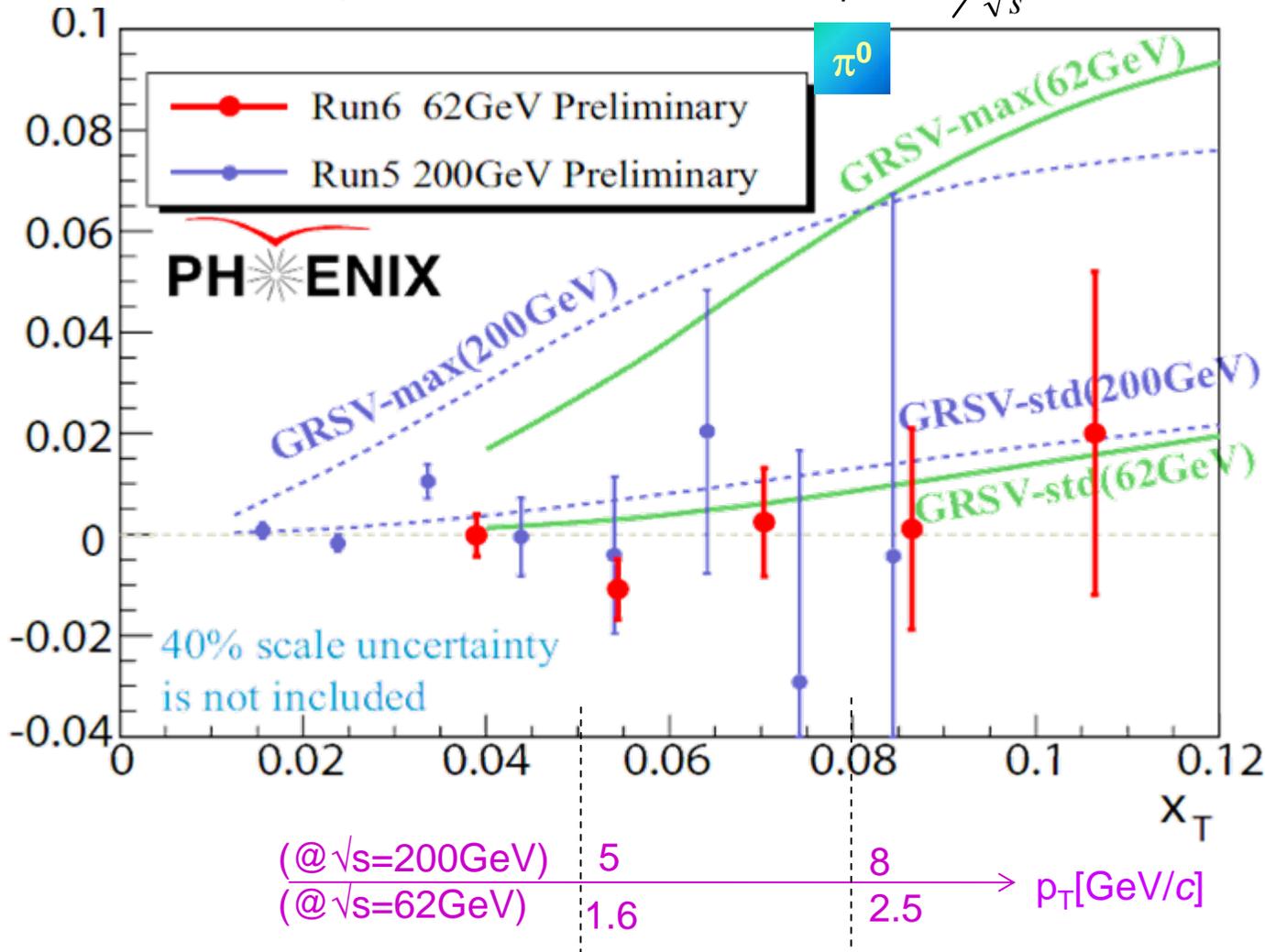
Lower collision energy ($\sqrt{s}=62\text{GeV}$)

$\times 0.1$ instantaneous luminosity,

$\times 100$ production for the same $x_T \equiv \frac{2p_T}{\sqrt{s}}$

Run6 62.4GeV $\sim 0.06 \text{ pb}^{-1}$

Run5 200GeV 1.8 pb^{-1}



!! Theory applicability at 62 GeV not yet verified by cross section

Various channels other than π^0

Jet components

| | |
|-----|-----------|
| g+g | π^0 |
| g+q | η |
| q+q | π^\pm |
| | h^\pm |
| | “jet” |

Direct photon

| | |
|-----|--------|
| g+q | photon |
|-----|--------|

Heavy particle

| | |
|-----------|-----------------------------|
| g+g | open charm to e to μ |
| | open beauty |
| J/ ψ | to e+e to $\mu+\mu$ |

Complementary measurements

PHENIX

Central arm

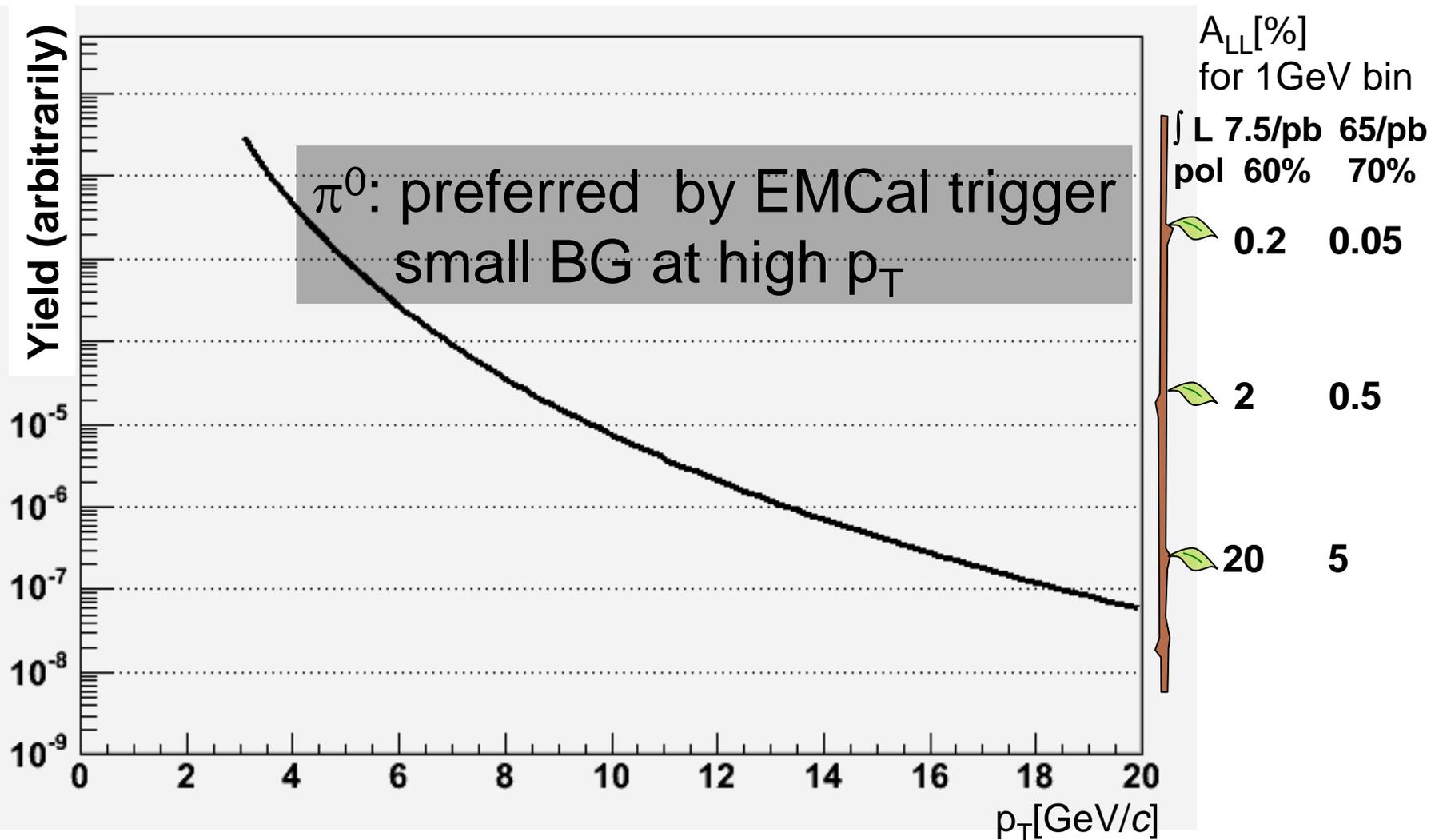
MPC (forward EMCAL)

Muon arm (but not only for muon)

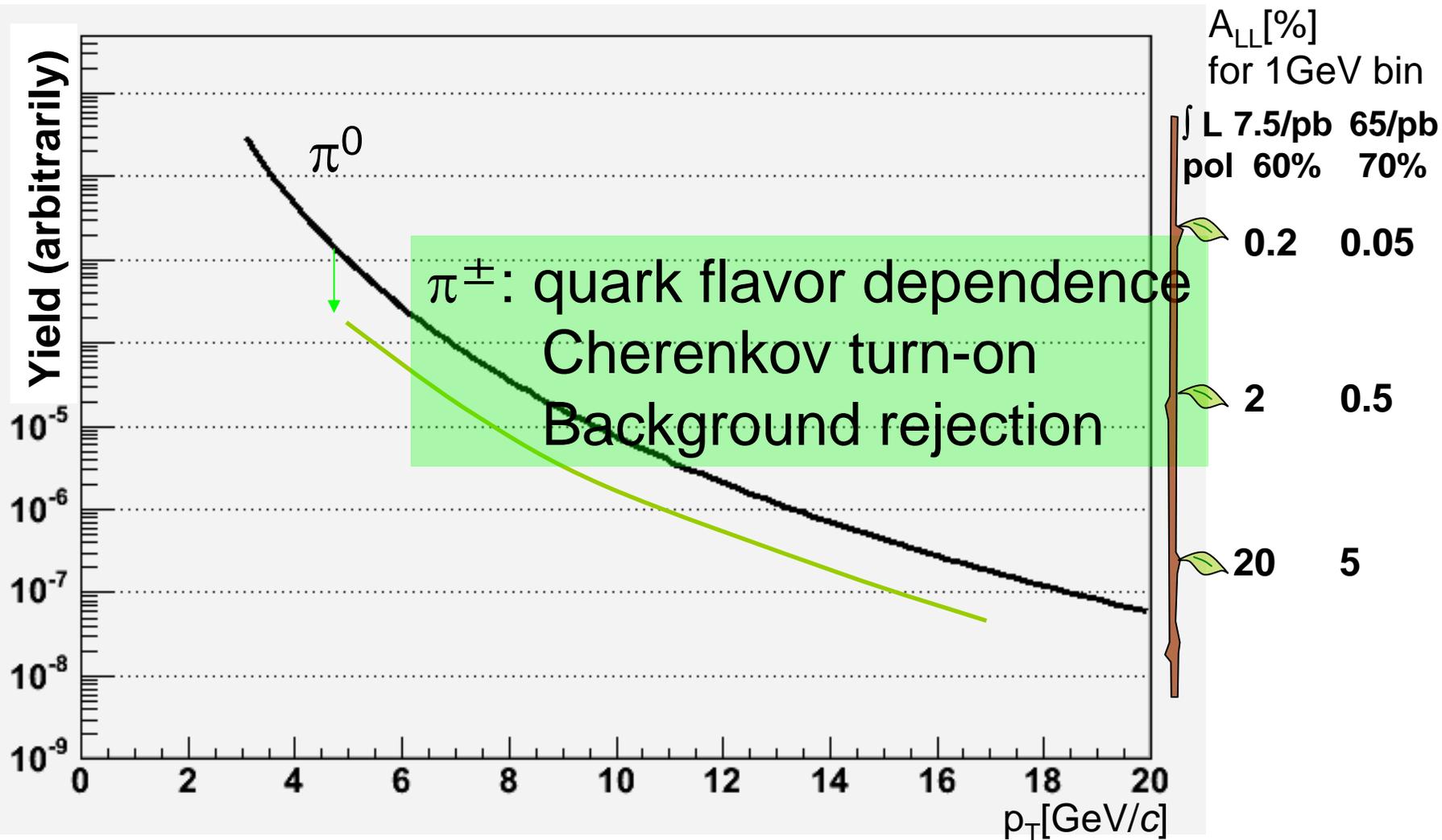
For the high precision,

Yield & purity

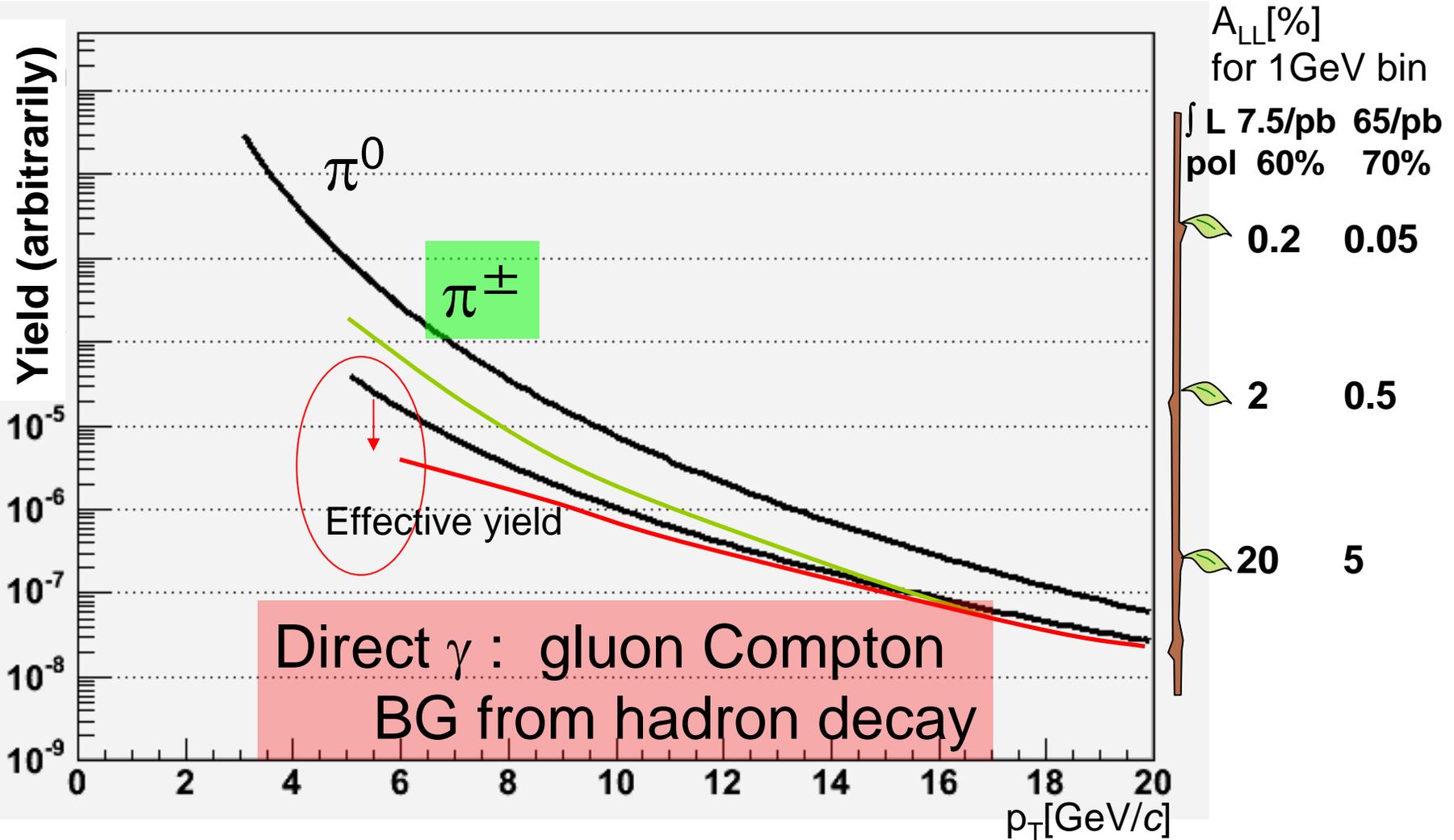
Yield comparison (PHENIX Central Arm)



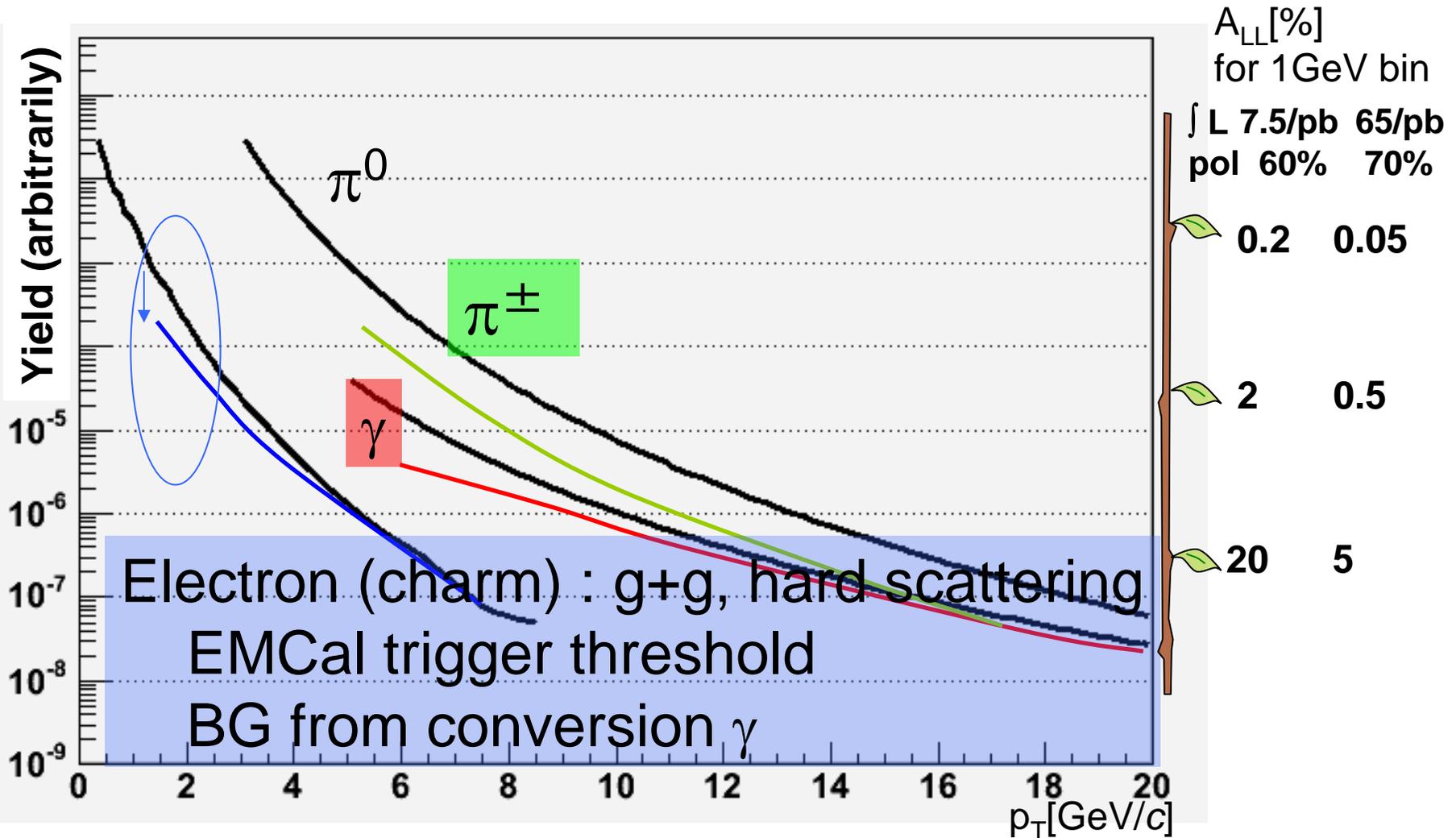
Yield comparison (PHENIX Central Arm)



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Yield comparison (PHENIX Central Arm)

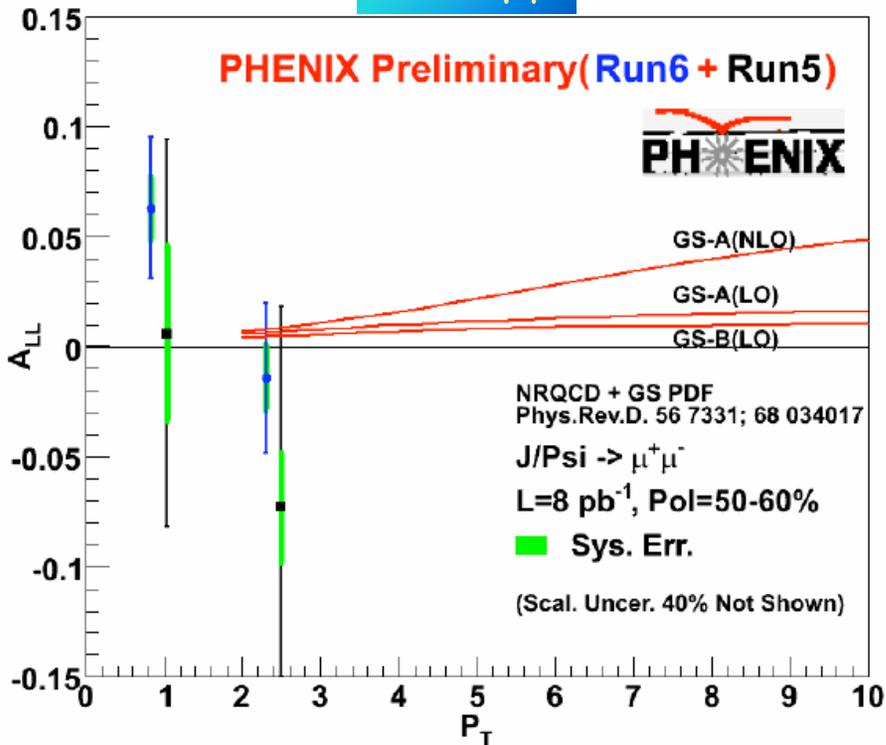


Waiting for high statistics.

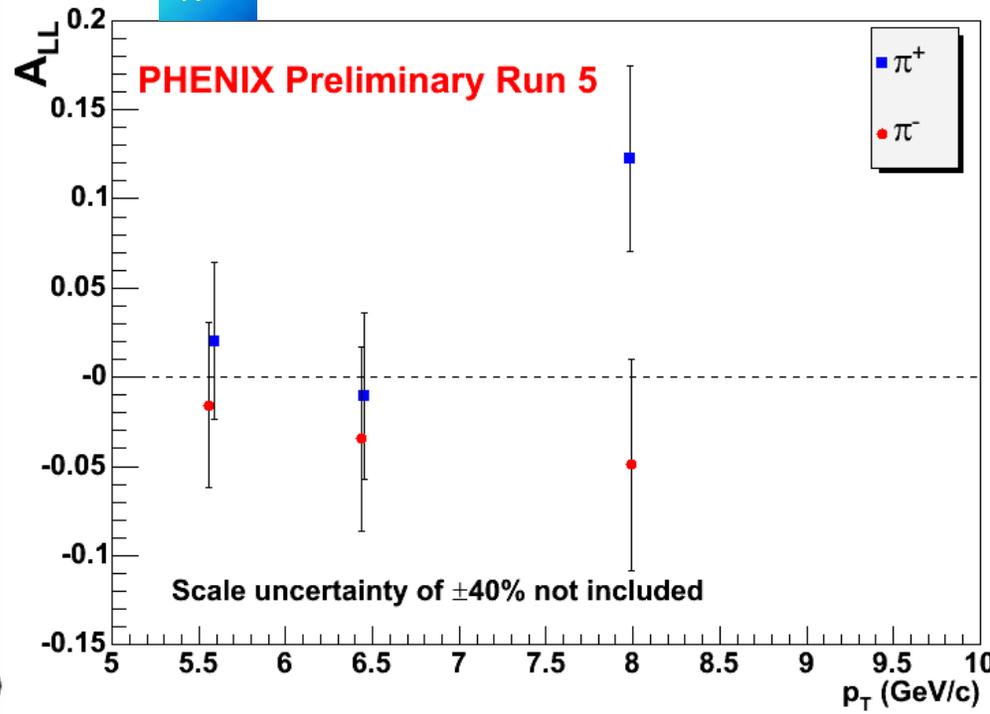
A_{LL} : various channels

J/Psi: $|y| = 1.2-2.4$

$J/\Psi \rightarrow \mu\mu$



π^\pm

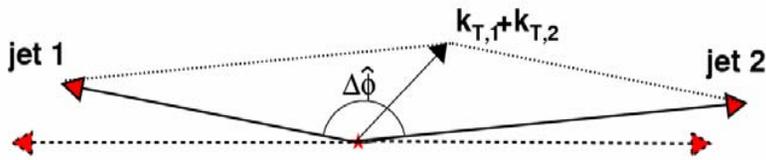


η , “jet” preliminary result from Run5, and others are under way.

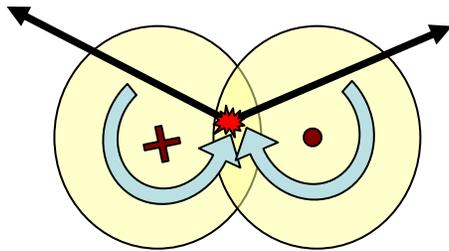
Complementary measurements to high statistics π^0 measurement

Di-Hadron Azimuthal Correlations

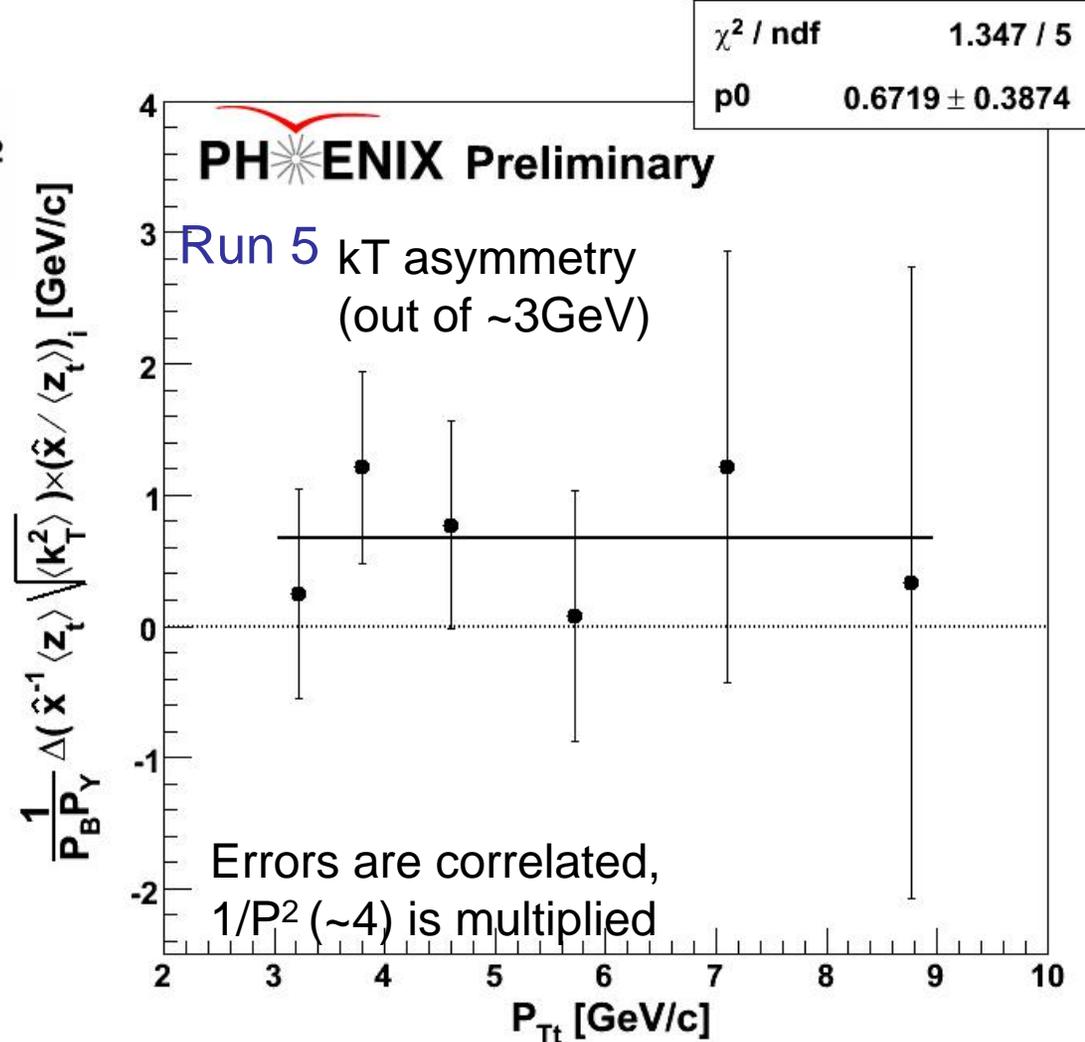
With $\pi^0 - h^\pm$ correlation



Spin-correlated transverse momentum (orbital angular momentum) may contribute to jet k_T .



Possible helicity dependence



Summary

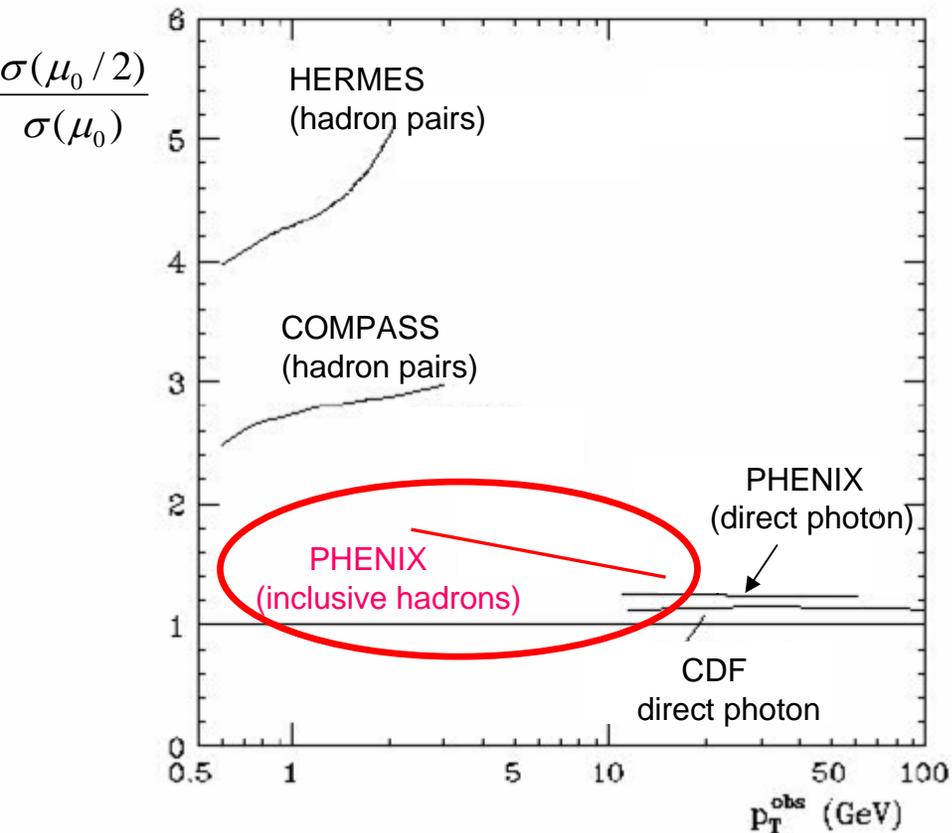
- ▶ With RHIC PHENIX, we measured production cross sections of various particles in $p+p$ collisions at $\sqrt{s}=200\text{GeV}$.
The results confirm our theoretical understanding of hard scattering, which is important for the next step (= measurement of proton spin structure)
- ▶ Double helicity asymmetry measurement of π^0 excludes a large Δg scenario.
- ▶ From other channels, complementary results will be obtained.
- ▶ Does the angular momentum play a big role? Jet k_T asymmetry may be related.
- ▶ The longitudinal polarization program at $\sqrt{s}=200\text{GeV}$ will be accomplished with about 70pb^{-1} , 70% polarization in 2008.
- ▶ PHENIX detector upgrade project \Rightarrow talk by J. Lajoie session 9 (Apr.19th)



backups

pQCD Scale Dependence at RHIC

Theoretical uncertainty of pQCD calculations in channels relevant for gluon polarization measurements:



π^0 data vs pQCD with different factorization scales:

